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GEOPHYSICS.—*Deformation and temperature.*[1] P. G. NUTTING, U. S. Geological Survey.

A steel tape is cooled by stretching, rubber is warmed. In either case the thermal effect is sensibly proportional to the elongation and is many times as great as the external work causing it. We say that the tape is cooled because intermolecular forces are weakened by the stretching although the strain is far within the elastic limit and strictly reversible. Similarly rubber is heated because the stretch pulls chains of molecules into line thus increasing internal potential. But to permit a balance of the energy equation, each of the above arguments must be reversed. All the energy change is not taken into account.

When water vapor, saturated at 25°, is liquefied by compression, the external work required is equivalent to 32.8 calories per gram of water condensed. But the condensed water immediately does 17 times as much work on itself, releasing 549.5 calories per gram. The large gain in internal kinetic energy which this represents of course comes neither from the external work nor from released internal potential but from the great increase in both pressure and concentration incident to the change in state.

These instances go to indicate the dominant part played by molecular physics in the heat changes due to deformation. It is proposed here to present and analyze some of the best data available, drawing such deductions from thermodynamical reasoning as seem admissible and pertinent to geological problems.

[1] This material was prepared in connection with a discussion of the internal pressures in adsorbed films, but since it is of geological rather than chemical interest, it is here published separately.

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When a gas is compressed, the heat generated is precisely equal to the work done in compression. If allowed to expand, doing work, it is cooled, otherwise it is not. In any case, the heat lost is equal to the work done in expansion. When water is stirred, the thermal energy generated is exactly equal to the work of stirring (Rowland's experiment). Our established value of the mechanical equivalent of heat ($4.18 \times 10^7$ ergs/calorie) was thus determined. In these instances powerful intermolecular forces (internal pressures) were not called into play—in gases they do not exist; in the stirred water they ended as they began. Even in Rumford's experiment of measuring the heat developed by boring a cannon with a dull tool, he was in error apparently only by the energy represented by the permanent strain in the chips. But for this energy of internal strain, the thermoelastic and thermoplastic problems would be very simple, heat developed would equal work done and if either were known the other could be easily computed. But the internal work in compressed liquids and in compressed and deformed solids is usually many times as large as the work done, is positive for some substances and strains, negative for others, and varies with both temperature and pressure.

The general theory of heating by compression (applicable to liquids and gases) was developed by W. Thomson (Lord Kelvin) about 1850, apparently as a result of a controversy with Clausius over the latter's use of Carnot's function, and in collaboration with Joule on the determination of the mechanical equivalent of heat. His paper was read March 17, 1851, before the Royal Society of Edinburgh.[2] In a briefer but more general paper[3] he later gave general equations applicable to any deformation. Haga in 1882 completely verified Kelvin's equations for the special case of a stretched wire,[4] and later Wassmuth did the same for torsional deformation[5] and for bending.[6]

If an external pressure $p$ exerted on a body decreases its volume $v$ by the amount $dv$ then the work done $dw = pdv$. But the total thermal energy generated in unit mass by this compression is

$$Pdv = C_p dT \tag{1}$$

where $P$ is the (thermodynamic) internal pressure, $dv$ is change in

[2] Trans. Roy. Soc. Edinburgh **20**: 261–288.
[3] Phil. Mag., January, 1878.
[4] Wied. Ann. **15**: 1. 1882.
[5] Drude's Ann. **11**: 146. 1903.
[6] Drude's Ann. **13**: 182. 1904.

specific volume, $C_p$ is mean specific heat at constant pressure and $dT$ is the temperature change. Hence

$$\frac{dT}{dv} = \frac{P}{C_p} \tag{2}$$

This last is the celebrated Kelvin formula of 1851 for the change of temperature with compression. Equation (1) is given as a simple plausible approach, not a rigorously proven relation. In all strict derivations of this formula, unknown functions are introduced in the initial energy equations and these functions afterward determined by rather laborious mathematical thermodynamics. Thermodynamic internal pressure $P$, like absolute temperature $T$, is to be regarded as convenient semi-fiction, having a perfectly definite meaning but incapable of direct physical measurement. From simple physical mechanics it is evident that internal cohesive pressure is but one of four in equilibrium in any steady state. $p + P = \pi + \kappa$ where $\pi$ is a distending pressure due to molecular resistance to compression and $\kappa$ is the kinetic pressure due to heat motion, as intensively developed by T. W. Richards during the last 15 years. Perhaps thermodynamic internal pressure $P$ is identical with the physical reality as Richards has assumed but the assumption appears unwarranted in the present state of development of the subject.

Since $dT/dp = dT/dv \times dv/dp$ and $dv/dp = v\beta$, the change of temperature produced by a change $dp$ in external pressure is

$$\frac{dT}{dp} = \frac{T\alpha v}{C_p} \tag{3}$$

The ratio of the heat generated to the external work done is

$$\frac{dH}{dw} = \frac{C_p dT}{p dv} = \frac{P dv}{p dv} = \frac{P}{p} \tag{4}$$

simply the ratio of the internal pressure to the external pressure doing the work of compression.

In using any of these formulas, all energies must be expressed in the same units, either ergs or calories. One calorie $= 4.183 \times 10^7$ ergs. Pressures are in dynes/cm$^2$ and $v$ and $dv$ refer to specific volume (volume of unit mass). $C_p$ refers to unit mass.

If the body deformed be a wire or tape stretched by a weight, the thermal effect is a cooling since the internal cohesive pressure opposes

extension and thermal expansion is positive. A formula similar (in form) to (3) may readily be developed

$$\frac{dT}{dF} = -\frac{Tal}{C_p} \tag{5}$$

$T$ is absolute temperature, $dT$ the change in temperature caused by the weight or tension $dF$ in dynes. $a$ is the expansion per degree and $l$ the length per unit mass (cm/gm). This formula has been completely verified by every observer who has determined $a$ and $C_p$ on the specimen actually used.

To illustrate the magnitude of the various factors involved, the following table has been computed from data selected from a magnificent set obtained with a steel tape hung in the Washington Monument by C. E. Van Orstrand and his assistants in April, 1907, and unfortunately still unpublished. I have selected the lengths observed 4 minutes after the load was applied. Readings, all taken near that temperature, are corrected to 7.5°C. hence $T = 280.6$ absolute. The dimensions of the tape were 14685 × 0.640 × 0.0165 cm. = 155.07 cc. Section 0.01056 cm², density 7.70, mass 1194 grams, length/mass 12.30 cm/gm. The specific heat was taken as 0.115 cal/gm/deg throughout. The coefficient of expansion was taken as .00001185 for small loads and varied considerably with the strain as indicated.

TABLE 1.—THERMODYNAMIC DATA ON STEEL TAPE

| *Load (Kg)* | *Yield (cm)* | *Temp. Drop.* | *Yield (cm/Kg)* | *Ext. work (Ergs/gm/10 Kg)* | *Ht. Loss (Ergs/gm/10 Kg)* | *Thermal Expn.* | *Internal Tension (Kg)* |
|---|---|---|---|---|---|---|---|
| 10 | 7.67 | .085 | .7670 | 31468 | 408600 | $11.85 \times 10^{-6}$ | 129.8 |
| 20 | 15.37 | .17 | .7685 | 31591 | 413400 | 11.99 | 130.9 |
| 30 | 23.09 | .29 | .7697 | 31706 | 576800 | 16.73 | 181.9 |
| 40 | 30.85 | .44 | .7712 | 31838 | 721000 | 20.91 | 226.5 |
| 50 | 38.63 | .55 | .7726 | 31969 | 576800 | 16.73 | 180.4 |
| 60 | 46.45 | .65 | .7742 | 32100 | 456700 | 13.24 | 142.3 |
| 70 | 54.31 | .73 | .7759 | 32240 | 413400 | 12.00 | 128.2 |
| 80 | 62.20 | .82 | .7775 | 32371 | 408600 | 11.85 | 126.2 |
| 90 | 70.12 | .90 | .7791 | 31519 | 408600 | 11.85 | 125.6 |
| 100 | 78.08 | .99 | .7808 | 32658 | 408600 | 11.65 | 125.1 |

The yield per kg increases slightly but steadily with the load, 5 times as much as would be accounted for by the decreased cross section, indicating a progressive weakening of the structure. The thermal effect per kg on the other hand goes through a pronounced maximum at a 30 kg load. The external work done by each kg increment

in the load is given in the fifth column and the corresponding thermal effect in the sixth. The latter is computed from the temperature change, mass and specific heat. Mechanical and thermal energies are reduced to the same unit, ergs per gram per 10 kg increment in load.

The thermal expansion for this tape under small loads was taken as .00001185 per degree and this value in equation (5) gives a temperature drop of .085 degree for a 10 kg load as observed. Since this is the chief variable in the expression (5) for $dT/dp$, it has been computed in the seventh column assuming $T$, $l$ and $C_p$ as constant. The results indicate a maximum expansion per degree (.0000209) at a load of 30 kg, hence a maximum yield to internal kinetic agitation is given by but a moderate deformation (0.2 per cent). Steel treaters find a (compressive) deformation of about 8 per cent best conducive to crystal growth on annealing.

In the last column are given the internal tensions developed by stretching computed by a formula precisely similar to (4). These values are simply those of the sixth column divided by those of the fifth and multiplied by 10 to give tension in kg. The maximum tension developed (226.5 kg) is not far below the breaking strength of the tape. At the higher loads there appears to be an interlocking of the grains which relieves this tension somewhat.

It is of interest to compute the two remaining pressures of the four which are in equilibrium within the tape at each load. The applied tensions (loads) and the opposing cohesive tension $P$ were given above. The kinetic repulsive pressure $\kappa = T\alpha/\beta$ is readily computed from the absolute temperature $T$ and the coefficients of thermal expansion ($\alpha$) and the tensile yield ($\beta$). Contact pressure $\pi$ is obtained by difference. All are in kg.

TABLE 2.—THE INTERNAL PRESSURES IN STEEL TAPE

| $p$ | $P$ | $\pi$ | $\kappa$ | $\alpha \cdot 10^6$ | $\beta \cdot 10^{12}$ |
|---|---|---|---|---|---|
| 10 | 129.8 | 56.1 | 63.7 | 11.85 | 53.29 |
| 20 | 130.9 | 57.4 | 63.5 | 11.99 | 53.40 |
| 30 | 181.9 | 82.4 | 89.5 | 16.73 | 53.49 |
| 40 | 226.5 | 107.1 | 109.4 | 20.91 | 53.59 |
| 50 | 180.4 | 81.2 | 89.2 | 16.73 | 53.69 |
| 60 | 142.3 | 61.9 | 70.4 | 13.24 | 53.80 |
| 70 | 128.2 | 54.5 | 63.7 | 12.00 | 53.92 |
| 80 | 126.2 | 53.4 | 62.8 | 11.85 | 54.03 |
| 90 | 125.6 | 53.0 | 62.6 | 11.85 | 54.14 |
| 100 | 125.1 | 52.7 | 62.4 | 11.85 | 54.26 |

From an engineering standpoint, the cohesive tension $P$ is likely to be of considerable interest. It gives information as to the nature of the yield under stress not given by Young's Modulus, the elastic limit, or Poisson's ratio.

The formulas given above, (2), (3) and (4), are readily adapted to geological problems involving heating by compression and rupture. Those applicable to shear and friction will be developed below. Since compressibilities are low and compressions small, even at rupture, volume changes are small. Since no elastic or thermal properties are very uniform throughout a mass, only rough values can be obtained. If the volume change be given, the corresponding temperature change is readily computed from (2). $v$ is the volume of unit mass and $dv$ the change in specific volume. If the thermal expansion and compressibility of the material in question are not available, we may take for a rough (maximum) value of $P$ the crushing strength, and for the change in temperature $dT = Pdv/C_p$ even though the compression be but a small fraction of the elastic limit. For example, a rock having a crushing resistance of 10,000 lbs/in$^2$ ( = 68.90 $\times$ 10$^7$ dynes/cm$^2$) and a specific heat of 0.20 calories per gram (basalt, sandstone, granite, limestone) would change in temperature by 0.82 degree for $dv$ = 0.01 cc. For a rock of density 2.5 gm/cc the specific volume is 0.40, hence for $dv$ = 0.01 cc. the compression is 2.5 per cent. A compression of 1 per cent would mean a temperature elevation of 0.33°C.

If pressure instead of compression be known, either (3) or (4) may be used to compute $dT$ and the calculation offers no difficulty.

For the work done and the heat generated in overcoming friction, the relations are simple and the thermal quantities involved are small. If $F$ is the force required to move one surface over another and $W$ the force pressing the surfaces together, the coefficient of friction, $k = F/W$, irrespective of the area in contact. The work $FS = kWS$ is required to push one surface a distance $S$ over another. This is $FS/A = kWS/A = kW_1S$ per unit area where $A$ is the area and $W_1$ the weight per unit area or pressure. In the absence of deformation away from the contact plane and of grinding at the contact, this work per unit area is equal to the heat developed per unit area $H_1$ ( = $H/A$) = $kW_1S$. For example, take $W_1$ = 1000 lbs/in$^2$ ( = 68.9 $\times$ 10$^6$ dynes/cm$^2$), a displacement of 1 cm ($S$ = 1) and $k$ = 0.20. Then $H_1$ = 13.8 $\times$ 10$^6$ ergs = 0.33 calorie/cm$^2$. This is sufficient to heat a layer of ordinary rock 1 cm thick 0.8°C. Other distances of slip and other pressures would give thermal effects in direct proportion. If grinding

occurs, the thermal effect may readily be calculated roughly from (4) taking for $P$ the crushing strength.

The thermal energy developed by shear appears never to have been observed or computed. A theoretical formula may readily be derived from Kelvin's original general equations[7] for any deformation whatever by making five of the six coördinates constant and taking the variation of the remaining one (an angle) in its relation to energy developed and the thermal effect. But this formula involves properties of a body not readily determinable and for practical purposes it is better to treat shear as distributed friction.

If any plane slides a distance $S$ over the next plane and the average thickness involved is $t$, then $S/t$ is the angle of shear. The work done is $H_1 = kW_1S$ as above. The number of slip planes in unit thickness is $1/t$. Hence the work done in unit volume is $kW_1S/t$ or simply $kW_1\alpha$ where $\alpha$ is the angle of shear. Taking $k = 0.7$ and $W_1 = 10{,}000$ lbs/in$^2$ (limestone or granite) and $S/t = 0.01$, the work done $= 0.5 \times 10^7$ ergs $= 0.12$ cal per cubic centimeter corresponding to a temperature rise in average rock of 0.2°C. If the deformation is sudden to near the elastic limit the thermal effect might rise to five or ten times this, if moderate and slow it would be very much smaller.

GENETICS.—*The genetical constitutions of* Oenothera pratincola *and its revolute-leaved mutations.*[1] FRIEDA COBB BLANCHARD, University of Michigan. (Communicated by H. H. BARTLETT.)

## THE EARLY OCCURRENCE AND BEHAVIOR OF THE REVOLUTE-LEAVED MUTATIONS OF *Oenothera pratincola*

Several accounts of certain revolute-leaved mutations of *Oenothera pratincola* have been written in the past twelve years (Bartlett, 1915; Cobb and Bartlett, 1919; Cobb, 1921).[2] A better understanding of the genetical constitutions of these forms now calls for the present paper. The data presented in the earlier papers are explained by the constitutions then suggested; but further investigations with them and with closely related forms have provided an explanation both simpler and wider in application.

[7] Phil. Mag., January, 1898, equations 6, 8, 12, 13.

[1] Papers from the Department of Botany of the University of Michigan, No. 268. Received February 1, 1929.

[2] See list of references at end of paper.

The situation may be briefly summarized as follows: In 1912 seed was collected by Professor H. H. Bartlett from eight plants of *Oe. pratincola* growing wild near Lexington, Kentucky. The strains descended from these eight plants are morphologically alike, but one of them, designated as strain E, is genetically different from the other seven (of which strain C is used as a typical example).

Strain C produces in every generation a small number of mutations of several kinds. Mutations of some of these types occur also in strain E; but much more conspicuous in strain E is the great number of mutated individuals with a striking characteristic not occurring in the other strains. These characteristic mutations of strain E are of at least four distinct kinds, but all are alike in having narrow, strongly revolute leaves, and in producing nothing but revolute-leaved plants in their progenies.

As may be seen from Table 1, the cultures of the $F_1$ generation from plant E contained only a small number of revolute plants (only two in a progeny of 522), a number comparable to the mutations occurring in strain C. Of the four plants chosen as the parents of the $F_2$ generation, three still gave only moderate numbers of revolute mutations (approximately 8%, 6%, 11%); the fourth, which gave 51% revolute plants, is the "mass-mutating" line of strain E. We are still carrying in culture mut. *formosa* from this source (now in its 14th generation from the original plant E), but unfortunately the f. *typica* of the mass-mutating line has been lost. Brief descriptions of the revolute forms have already been published (Bartlett, 1915).

Mut. *formosa* is normally fertile and vigorous. As will be seen from Table 2, it gave in the $F_1$ progeny some plants of each of the other three revolute types; but in more recent generations it has been breeding practically true.

Mut. *albicans*, as it first appeared in the garden, was vigorous, but produced few good seeds. As shown in Table 2, the original plants of this form produced in the $F_1$ generation progenies consisting of three of the four revolute types (muts. *albicans*, *revoluta* and *setacea*) but *not* mut. *formosa*. After the season of 1915, the experiment garden was moved from Maryland to Michigan, and since that time the very few plants of mut. *albicans* which have been observed in the seed pans have failed to mature. Consequently, any unusual revolute seedling resembling this form has been recorded as mut. *albicans*, though it is very possible that they may not all have been alike.

Mut. *revoluta* was practically sterile as it first appeared. Table II

TABLE 1.—Analysis of the Progenies of the Original Plant of *Oe. pratincola* Strain E; of Four of its Offspring (One of them Showing Mass-Mutation); and of the $F_2$ Plants from Two of the $F_1$ Plants. Plants not Otherwise Designated are f. *typica*.

| Nature of culture | Pedigree of parent | Analysis of progeny | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | f. typica | mut. formosa | mut. albicans | mut. revoluta | mut. setacea | Flat-leaved mutations | Percentage of reduplicated plants in culture | Percentage of mut. setacea in culture |
| $F_1$ progeny of original plant of strain E | *Unknown* | 517 | 0 | 1 | 0 | 1 | 3 | 0.4 | 0.2 |
| $F_2$ generation | E—5 f. *typica*[a] | 194 | 4 | 15 | 15 | 172 | 4 | 51 | 43 |
| | E—19 f. *typica* | 954 | 0 | 0 | 24 | 54 | 0 | 8 | 5 |
| | E—25 f. *typica* | 610 | 0 | 1 | 12 | 23 | 1 | 6 | 4 |
| | E—43 f. *typica* | 566 | 0 | 2 | 5 | 63 | 1 | 11 | 10 |
| | E—36 mut. *latifolia*[b] | 95 | 0 | 5 | 2 | 29 | 3+ 48 mut. lat. | 20 | 16 |
| $F_3$ in mass-mutating line | E—5—229 f. *typica* | 226 | 10 | 57 | 54 | 644 | 5 | 74 | 62 |
| | E—5—208 mut. *angustifolia*[c] | 2 | 4 | 2 | 21 | 475 | 1 | 99 | 94 |
| | E—5—208 mut. *angustifolia*[c] × E—5—229 f. *typica* | 0 | 0 | 0 | 4 | 168 | 1 | 99 | 97 |
| | E—5—229 f. *typica* × E—5—208 mut. *angustifolia*[c] | 10 | 0 | 1 | 4 | 99 | 4 | 88 | 84 |
| | E—5—229 f. *typica* × E—5—206 mut. *formosa*[d] | 7 | 0 | 1 | 0 | 121 | 4 | 92 | 91 |
| | E—5—229 f. *typica* × E—5—182 mut. *albicans*[d] | 1 | 0 | 0 | 1 | 12 | 0 | 93 | 86 |
| Total | | 286 | 14 | 61 | 84 | 1519 | 15 | 85 | 77 |
| $F_3$ in non-mass-mutating line | E—43—89 f. *typica* | 96 | 0 | 0 | 0 | 1 | 3 | 1 | 1 |
| | E—43—72 f. *typica* | 49 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | E—43—74 f. *typica* | 188 | 1 | 0 | 3 | 3 | 2 | 4 | 2 |
| Total | | 333 | 1 | 0 | 3 | 4 | 5 | 2.3 | 1.2 |

[a] This is the origin of the mass-mutating line.

[b] See Bartlett, 1915, p. 443.

[c] Mut. *angustifolia* is a narrow-leaved (flat) mutation of *Oe. pratincola* which behaves exactly as f. *typica* in breeding.

[d] Crosses of this kind have repeatedly been demonstrated to give the same results as self-pollinations of the egg parents.

shows that the single $F_1$ progeny of this form consisted of muts. *revoluta*, *setacea*, and *albicans*. Since this culture was grown, no plant of mut. *revoluta* from self-pollinated plants of strain E has survived the seedling stage.

Mut. *setacea* differs from the other three forms in several respects—in fact, as will be shown later, it is in a class by itself, though revolute, and really differs more from mut. *formosa*, than the latter does from f. *typica*. As it first occurred, mut. *setacea* was not only difficult to

TABLE 2.—AN ANALYSIS OF THE PROGENIES OF THE FOUR REVOLUTE-LEAVED MUTATIONS OF *Oe. pratincola*. PLANTS NOT OTHERWISE DESIGNATED ARE F. *typica*.

| *Type of parent* | *Pedigree of parent* | *Analysis of progeny* | | | |
|---|---|---|---|---|---|
| | | *mut.* formosa | *mut.* albicans | *mut.* revoluta | *mut.* setacea |
| mut. *formosa* | E—5—199 mut. *formosa* | 883 | 1 | 4 | 194 |
| | E—5—206 mut. *formosa* | 130 | 2 | 0 | 14 |
| | E—5—199 mut. *formosa* × E—5—217 f. *typica*[a] | 218 | 0 | 0 | 91 |
| | E—5—206 mut. *formosa* × E—5—229 f. *typica*[a] | 151 | 0 | 3 | 23 |
| Total | | 1382 | 3 | 7 | 322 |
| mut. *albicans* | E—19—67 mut. *albicans* | | 36 | 3 | 226 |
| | E—5—182 mut. *albicans* | | 7 | 3 | 59 |
| Total | | | 43 | 6 | 285 |
| mut. *revoluta* | E—5—190 mut. *revoluta* | | 1 | 17 | 5 |
| mut. *setacea* | E—5—17 mut. *setacea* | | | | 140 |
| | E—5—20 mut. *setacea* | | | | 8 |
| | E—5—66 mut. *setacea* | | | | 31 |
| | E—5—135 mut. *setacea* | | | | 14 |
| Total | | | | | 193 |

[a] Crosses of this kind have repeatedly been demonstrated to give the same results as self-pollinations of the egg parents.

cultivate, but, like mut. *albicans*, gave very few good seeds. Table 2, however, gives satisfactory evidence that this form *breeds true*. It differs from the other three revolute forms also in its extremely small size and in its great numbers. It will be observed in Table 1 that the difference between the mass-mutating and non-mass-mutating strains lies in the prevalence of mut. *setacea*. The other three revolute-leaved forms occur with about the same frequency in all lines of strain E; but the number of individuals of mut. *setacea*, compara-

tively moderate in the other with three lines, is excessive in the fourth, or "mass-mutating" line.

Upon their first appearance, experimenting was begun with all four of these revolute-leaved mutations. Breeding data obtained from the three more sterile forms however, were few. Mut. *formosa* seemed more promising as material. And when the garden was moved to Michigan, after the season in which the $F_1$ generations of these forms were grown, it proved impossible to carry on any of the revolute lines except mut. *formosa*. Either the climate in Michigan is more unsuitable for these forms, or, more likely, the forms themselves are not as vigorous as at their first occurrence. Thus all attention since that time has been given to experiments involving mut. *formosa*. However, something has been learned of mut. *setacea* from its mere occurrence in progenies of self-pollinated plants of f. *typica* and mut. *formosa*, from its representative in hybrid cultures, and from its parallelism to a certain other form.

## Results of Crosses between mut. *formosa* and f. *typica* of Strains E and C

An extensive series of crosses has been made between mut. *formosa* and f. *typica* of strains E and C. The results have already been published (Cobb and Bartlett, 1919; Cobb, 1921) but may be summarized as follows:

f. *typica* strain E × mut. *formosa*→f. *typica* (same progeny as self-pollinated f. *typica*)
mut. *formosa* × f. *typica* strain E→mut. *formosa* (same progeny as self-pollinated mut. *formosa*)
f. *typica* strain C × mut. *formosa*→f. *typica*
mut. *formosa* × f. *typica* strain C→f. *typica*, which instead of breeding true, produces in the $F_1$ generation a mixed progeny of the following proportions: 1 f. *typica*, true breeding; 2 f. *typica*, segregating in the next generation; 1 mut. *formosa*.

Inheritance, then, seems to be matroclinic in the cases of the first three crosses, and Mendelian in the fourth.

## The Earlier Explanation of the Results of the Crosses

The earlier explanation adopted (Cobb and Bartlett, 1919) assumed: (1) that all the forms involved are heterogametic (i.e., formed by the union of two unlike gametes, an $\alpha$ gamete—usually the egg—and a $\beta$ gamete—usually the sperm) and that there is among the fourteen chromosomes of each of the forms one (and the same) pair of freely segregating chromosomes; (2) that mut. *formosa* arises from f. *typica*

of strain E by a modification of a chromosome confined to the $\alpha$ group, giving to mut. *formosa* a factor for revoluteness of leaves in place of one for flatness in the other forms under consideration; (3) that, in the freely segregating pair of chromosomes, strain C carries a pair of dominant factors for flatness, which prevent the revolute character from appearing, (even though the $\alpha$ group with which they are associated has acquired the factor for revoluteness), and strain E and its mutation *formosa* carry the recessive allelomorphs of these factors—non-flattening factors, which do not prevent the revolute character from appearing in plants carrying the $\alpha$ which is modified by the factor for revoluteness ($\alpha'$); (4) that the $\beta$ group of chromosomes is identical in the three forms, the $\beta$ gametes differing only in the factor for flatness carried in the freely segregating chromosome. It was assumed that the constitutions of the other revolute-leaved forms were similar to that of mut. *formosa*, though breeding experiments were insufficient to establish this. The constitutions of the three forms and their hybrids were therefore written:

| | |
|---|---|
| Strain C, | $\alpha\beta$FF, flat, and, with respect to this character, immutable. |
| Strain E, | $\alpha\beta$ff, flat, mutable. |
| Mut. *formosa*, | $\alpha'\beta$ff, revolute. |
| Strain E × *formosa*, | $\alpha\beta$ff, flat, mutable. |
| *Formosa* × strain E, | $\alpha'\beta$ff, revolute, breeding true with respect to this character. |
| Strain C × *formosa*, | $\alpha\beta$Ff, segregating with respect to mutability. |
| (Strain C × *formosa*) $F_2$, | 1$\alpha\beta$FF, flat, immutable, breeding true.<br>2$\alpha\beta$Ff, flat, continuing the segregation of the $F_1$ generation.<br>1$\alpha\beta$ff, flat, mutable, otherwise breeding true. |
| *Formosa* × strain C, | $\alpha'\beta$Ff, flat, segregating with respect to revoluteness. |
| (*Formosa* × strain C) $F_2$, | 1$\alpha'\beta$FF, flat, non-segregating.<br>2$\alpha'\beta$Ff, flat, continuing the segregation of the $F_1$ generation<br>1$\alpha'\beta$ff, revolute, breeding true. |

## Respects in which the Earlier Explanation is Unsatisfactory

There are three respects in which this hypothesis is somewhat unsatisfactory. First, it assumes that the factor for revoluteness arises anew in strain E every time a revolute-leaved plant is produced—that each plant is, in truth, an original mutation. Second, it assumes both a factor for flatness, with an opposed factor for revoluteness (both confined to the $\alpha$ assemblage of chromosomes and therefore matroclinically inherited), and a factor for flatness with an allelomorph merely non-flattening in its effect, (as opposed to one producing revoluteness) in a freely segregating pair of chromosomes. Third, the $F_2$ generation of one of the crosses recorded (Cobb, 1921, page 8) failed to show the few revolute-leaved plants expected by this hypoth-

esis, though in all the other crosses made the hypothesis completely satisfies the facts. Under the new hypothesis it is easy to explain this "discrepancy," and this will presently be done.

## A New Hypothesis Offered

A new hypothesis, hereby presented, assumes that strains C and E are alike in constitution, except that $\beta$ of strain E carries a recessive factor for revoluteness, and $\beta$ of strain C its dominant allelomorph for flatness. These $\beta$ factors have no allelomorphs in $\alpha$; the chromosomes of $\alpha$ and of $\beta$ are not mates. As far as known, the $\alpha$ groups of chromosomes are identical in the two forms.

Also, because of a "weakness" (Blanchard, 1926, p. 148) of the $\alpha$ eggs, for some unknown reason, the $\beta$ gametes of strain E function more frequently as eggs than is normal for the species. Strain C has occasional functional $\beta$ eggs. These, when fertilized by $\beta$ sperms, as normally happens, give homogametic plants ($\beta\beta$), and as seems often to be the case when the two gametes are genetically alike, the plants are poor dwarfs ("runts") which attain a height of only a few inches and seldom even flower. Strain E produces a much larger proportion of functioning $\beta$ eggs. In this strain the homogametic plants thus produced are homozygous for the recessive factor for revoluteness and are therefore revolute-leaved mut. *setacea*, the dwarf member of the revolute-leaved series of mutations.

Mut. *formosa*, however, the revolute-leaved plant used most extensively in the experiments, is not, like mut. *setacea*, a homogametic plant. The new hypothesis assumes that, in f. *typica* of strain E, that particular chromosome of $\beta$ which carries the factor for revoluteness has, on several rare occasions, been exchanged (by whole-chromosome crossing over) with a chromosome of $\alpha$. This results in an $\alpha$ gamete carrying, in place of one of its seven chromosomes, the $\beta$ chromosome which bears the revolute factor. Such a gamete, fertilized, as it would be, by a normal $\beta$ gamete, gives a heterogametic ($\alpha\beta$) plant homozygous for the factor for revolute leaves. This is mut. *formosa*.[3] In the most unstable line of strain E, this phenomenon (the production of mut. *formosa*) has occurred approximately once in a hundred plants produced. This hypothesis, then, requires the functioning of a $\beta$ egg, rather than an original mutative change,

[3] Aside from making this form (mut. *formosa*) revolute-leaved, the only known effect of this $\beta$ chromosome in $\alpha$ is to increase in it slightly the general characteristics of homogametic ($\beta\beta$) plants (Blanchard, 1926).

for the production of each plant of mut. *setacea;* and a breaking away of one chromosome of a linkage group, rather than an original mutative change within a chromosome, for the production of each new plant of mut. *formosa* from f. *typica*.

Though the $\beta$ chromosome bearing the revolute factor, or its allelomorph, has ordinarily (i.e., in f. *typica*) no mate in the $\alpha$ group, it does find a mate in the identical $\beta$ chromosome acquired by the $\alpha$ gamete of mut. *formosa*. Doubtless these two chromosomes segregate freely in mut. *formosa*, but since they are identical there is no visible evidence of the segregation.[4]

If, now, this $\alpha$ gamete of mut. *formosa*, bearing as it does a $\beta$ chromosome carrying the revolute factor, is fertilized by a $\beta$ gamete carrying the allelomorph for flatness (such a gamete as $\beta$ of strain C) there are brought together two chromosomes differing only in a single factor. Mendelian behavior follows.

Mut. *setacea* is not only homogametic but also completely homozygous. Instead of fourteen different chromosomes, it has seven chromosomes in duplication. Just as in mut. *formosa* the two identical chromosomes are presumably freed from $\alpha$ and $\beta$ bondage and become an independent pair, so in mut. *setacea* the assumption is that all of the chromosomes pair.

The constitutions of the plants under discussion may now be written in conformity with the new hypothesis. When a factor is confined to the $\alpha$ or the $\beta$ group, the symbol is so placed as to indicate the fact. Symbols of factors in freely segregating chromosomes are separated from the $\alpha$ and $\beta$ signs. F represents the dominant factor for flatness: f, the recessive factor for revoluteness.

f. *typica* strain C = $\alpha$F$\beta$F
f. *typica* strain E = $\alpha$F$\beta$f
mut. *formosa* = $\alpha\beta$ff

mut. *formosa* × f. *typica* strain C → $\alpha\beta$fF → { 1$\alpha\beta$FF (flat, breeding true)[5]; 2$\alpha\beta$Ff (flat, repeating the segregation)[5]; 1$\alpha\beta$ff (revolute)[5] }

[4] Since this paper was written, Dr. C. G. Kulkarni has made a cytological examination of mut. *formosa*, and finds a ring of 14 chromosomes instead of a ring of 12 plus a pair, which is what one might expect. However, the breeding data accord so well with the hypothesis herein developed, and the correlations of the cytological findings with the genetical are still so little worked out, that one may look forward confidently to a future harmonization of the results.

[5] In all of these plants, the $\alpha$ eggs carry one chromosome which has a mate in any *pratincola* $\beta$ sperm.

## Consideration of the Single Case in which the Original Hypothesis Seemed at Variance with Results Obtained

The true-breeding flat-leaved plants of the $F_2$ generation of the cross shown above, those of constitution $\alpha\beta$FF have been designated "f. *typica* strain M (homozygous)" (Cobb, 1921). It was the cross f. *typica* strain E × f. *typica* strain M (homozygous) which gave a result (previously referred to) not quite in accordance with the expectation of the old hypothesis (Cobb, 1921, page 8). This cross is here written out, first with the constitutions originally suggested, and then with the newly adopted constitutions.

### A. Old Formulation

f. *typica* strain E ($\alpha\beta$ff) × f. *typica* strain M ($\alpha'\beta$FF) → $\alpha\beta$Ff →

- 1 $\alpha\beta$FF (flat, true breeding)
- 2 $\alpha\beta$Ff (flat, repeating the segregation)
- 1 $\alpha\beta$ff (flat, *except* for a few plants revolute-leaved *by mutation* (since it contains the mutating $\alpha$ of strain E and neither of the flattening factors), and producing revolute-leaved plants with the same frequency as does f. *typica* strain E)

The plants of the $F_2$ generation, which should have given progenies containing some plants revolute-leaved by mutation, failed to do so. This was the only case in which the original hypothesis did not seem fully to fit the facts, and further study seemed necessary (Cobb 1921, page 9).

### B. New Formulation

f. *typica* strain E ($\alpha$F$\beta$f) × f. *typica* strain M ($\alpha\beta$FF) → $\alpha$F$\beta$F

- Only flat-leaved, *never* revolute-leaved plants, since the factors for revoluteness are entirely absent from the plant.

As a matter of fact, the $F_2$ progenies from eight $F_1$ plants of this cross, totalling over 6,000 plants (Cobb, 1921, table 20, page 35) contained, as would now be expected, not a single revolute-leaved plant. According to the old hypothesis there might well have been, (by mutation of $\alpha$ to $\alpha'$) several hundred.

## SUMMARY

In brief, the behavior of *Oe. pratincola*, in respect to its revolute-leaved mutations, is now explained more simply and satisfactorily than formerly. Instead of a condition of high mutability to revoluteness in $\alpha$ of strain E, and a pair of factors for flatness in a pair of freely segregating chromosomes in strain C and their non-flattening allelomorphs in strain E, the new hypothesis requires only a single origin of the factor for revoluteness as a mutation in $\beta$ of strain E, and an allelomorph for flatness in $\beta$ of strain C. This explanation does not require any free pairing of chromosomes in *Oe. pratincola* f. *typica*, but does require one pair of independent—or at least homologous—chromosomes in mut. *formosa*.

Mut. *formosa* is thought to originate by a whole-chromosome crossover, when (very rarely), at reduction division, and $\alpha$ egg of f. *typica* strain E acquires that $\beta$ chromosome which bears the factor for revolute leaves. The fertilization of such an altered $\alpha$ egg by a normal $\beta$ sperm results in a zygote with a pair of identical chromosomes, which are thereafter free of $\alpha$ and $\beta$ bondage.

Further, the constitution of the dwarf mut. *setacea* is concluded to be $\beta\beta$, and its occurrence in such numbers in the "mass-mutating" line to be due not to "wholesale modification of female gametes" as at first suggested, but to the unusual functioning of $\beta$ eggs in this line.

As strain E was collected from the wild in 1912 it differed from the other strains collected at the same time only, so far as known, in having in $\beta$ the factor for revolute leaves. In the second garden generation, the progeny of one (E-5) of the four $F_1$ plants used as parents showed "mass-mutation"—the production of a large proportion of $\beta\beta$ plants. The $\beta$ gamete which went into the constitution of E-5 was relatively "strong" as an egg, or (more probably) the $\alpha$ was unusually weak, and approximately half of the functioning eggs were $\beta$ gametes. The other three progenies were normal, i.e., they did not show mass-mutation. In these three lines the revolute-leaved mutations occurred with about the same frequency as do the flat-leaved mutations in the other strains of *Oe. pratincola*. As far as *Oe. pratincola* is concerned, therefore, the phenomenon called mass-mutation by Bartlett has been satisfactorily explained. The other case of mass-mutation, that of *Oe. Reynoldsii*, will doubtless have as simple an explanation. In this conclusion Professor Bartlett concurs with the writer.


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## PALEONTOLOGY.—*A fossil member of the family Pegididae.*[1]

JOSEPH A. CUSHMAN, Sharon, Massachusetts.

Heron-Allen and Earland have recently described several species belonging to four new genera, and all included in a new family which they have called Pegididae.[2] The species present some very unusual forms and are from shallow tropical waters. These authors make the following note. "The wide distribution of the family in tropical seas would appear to connote a prolonged ancestry. Geological records at present give no evidence on this point so far as our own information goes. It is possible that early stages of the family's evolution may yet be found in tropical deposits, but, on the other hand, it must be recognized that coral sands and gravels such as the family now favours do not readily lend themselves to fossilisation."[3]

In view of this note, it is interesting to record a fossil species. One of the best known later Tertiary faunas which has essentially a shallow-water tropical character is that described from Kostej, Banat, Hungary, by Karrer.[4] This fauna contains many Miliolidae, including *Articulina* and *Hauerina*, with *Peneroplis* and *Spirolina* together with other forms of generally shallow-water tropical relationships. A considerable amount of material from Kostej in the writers possession was searched, with the result that a species of *Pegidia* was found, the first fossil record for the family. It is here figured and described.

**Pegidia karreriana** Cushman, n. sp.

Figs. 1 *a-c*

Test free, unequally biconvex, dorsal side more convex than the ventral; three chambers visible from the surface forming an irregular spire, earlier

[1] Received February 7, 1929.

[2] *On the Pegididae, a new family of Foraminifera.* Journ. Roy. Micr. Soc. **1898**: 283–299. *pls. 1–3, 1 text fig.*

[3] Op. cit., p. 288.

[4] *Die miocene Foraminiferen-fauna von Kostej im Banat.* Sitz. Akad. Wiss. Wien. **58**(1): 111–193. *pls. 1–5.* 1868.

chambers concealed by these three later ones, slightly inflated, fairly distinct from the ventral side, less so from the dorsal side except when wet; sutures not well marked, on the ventral side fairly distinct, on the dorsal side the suture between the last-formed chamber and the two preceding marked by a raised ridge; wall thick, on the ventral side smooth, on the dorsal ornamented by a series of irregular knobs; apertures consisting of a series of rounded pores along the region of the sutural line on the ventral side of the test.

Diameter 0.40 mm.; height 0.32 mm.

Holotype (Cushman Coll. No. 10,244) from the Miocene, Kostej, Banat region of Hungary.

At first glance, the surface resembles that of *Sphaeridia papillata* Heron-Allen and Earland, but the structure places it in *Pegidia*. Of the species of *Pegidia*, it is nearest to *P. pulvillus* Heron-Allen and Earland, but the surface is more coarsely ornamented and the biconvex form of the fossil species more

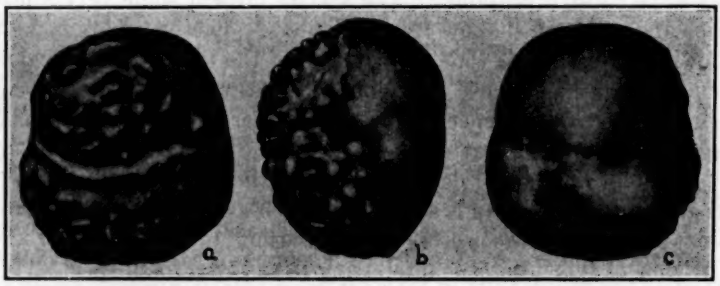



Figure 1.—*Pegidia karreriana* Cushman, n. sp., × 90. *a*, dorsal view; *b*, peripheral view; *c*, ventral view.

nearly symmetrical than in the recent one. *P. pulvillus* is described from DISCOVERY Station 283, off Annobon Island, Gulf of Guinea, 18–30 meters, from coral sand.

At first, it was thought that "*Discorbina turris* Karrer" described from Kostej might be the early stage of this species, but "*D. turris*" was found in the material and seems to be quite different with its ornamented ventral side and larger number of chambers.

This family contains some very queer forms and they appear to be exceedingly rare. They seem to have been derived from such genera as *Eponides*, *Lamarckina* or forms of *Discorbis* by a greater involution of the chambers. The development of a peculiar thickened plate which is finally perforated to form the apertures recalls somewhat the plate-like structure seen in *Cancris* and *Baggina*, the latter genus also becoming strongly involute. The peculiar perforated area of

*Cancris lateralis* (*Pulvinulina lateralis*) may be noted in this connection. The Pegididae are very closely related to this particular branch of the Rotalidae, but the relationship to the Globigerinidae mentioned by Heron-Allen and Earland seems much more remote. It is true that *Candeina* has rows of pores along the sutures, but it is not through a special plate as in these groups. The Pegididae have evidently become specialized in another direction, and instead of becoming thin, large-apertured, with delicate spines and fitted for pelagic life, have adopted a very heavy, thick test, with a reduction of the aperture to a minimum, adapting themselves thus to the rough treatment received in rather swift currents and coarse bottom sediments.

The genus *Physalidea* with two species, each described from single specimens, needs more material to show its exact relationship to the other genera included in the Pegididae.

## PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

### THE ANTHROPOLOGICAL SOCIETY

On February 21, 1928, Mr. O. F. Cook, of the United States Department of Agriculture, addressed the Society on the subject: *Peru as a primitive center of agriculture.* The ancient Peruvians may be said to have attained the highest development of the art of agriculture, in their system of terracing and artificial placement of the soil. The cost in labor was enormous, but the improvements were permanent. The fertility of the soil was not lost by erosion, and may even have increased with the lapse of time. The terraced lands of the valleys of the eastern Andes undoubtedly have been cultivated continuously for many centuries and still are highly productive. The very specialized forms of agriculture and attendant arts in Peru indicate a very long period of development, and the indigenous character of the development is shown by facts of domestication.

The agriculture of the table-lands certainly was indigenous, since it was based entirely on the domestication of endemic high-altitude plants and animals, but there is nothing to indicate that the agriculture of the tropical valleys was derived from other regions. Primitive people who took refuge in these narrow, shut-in valleys of the eastern slopes of the Andes were under the greatest pressure to adopt a settled existence and to make every possible use of any local plants that could furnish food. The textile arts were carried to high degrees of perfection with cotton and other plant fibers, and with the wool of llamas, alpacas and vicuñas. As the higher elevations were attained, accurate knowledge of the motions of the sun became necessary, to determine the season for planting crops. The series of plant and animal domestications covered the entire range of habitable conditions, from the tropical lowlands, through the temperate valleys to the arctic climate of the high plateaus, where agriculture was carried above 14,000 feet.

The number of species of plants and animals that were domesticated and used in Peru was much greater than in Mexico or other parts of America. A list of 91 native Peruvian plant names was published in the Journal of Heredity for March, 1925, including all of the more prominent cultivated species. Most of the plants that were cultivated in other regions were also known in Peru, and may have been domesticated originally in the eastern valleys of the Andes. The ancient Peruvians had every plant that was of first-rank importance in other parts of tropical America. Many degrees of agricultural specialization are still represented in Peru among very primitive people, and may afford the best surviving pictures of early stages of human progress. Having recognized that Peru was a center of domestication, this fact may enable us to follow and interpret the development of agriculture and civilization in other parts of America.

On October 16, 1928, Dr. JOHN M. COOPER, of the Catholic University, addressed the Society on the subject: *Field Notes on the Ojibwa of northern Ontario.* He gave a short account of the results of visits made in September, 1928, to the Ojibwa bands living around Lake of the Woods and Rainy Lake in Ontario. The purpose of the trip was to trace the western distribution of a number of traits previously determined as existing in Quebec, James Bay, and Albany River areas. He found that the culture traits characteristic of the eastern Algonkian region extend to the Rainy River and Lake of the Woods district. Following are some of the features of the Rainy River and Lake of the Woods culture. The typical family hunting-ground complex obtains. There were formerly no chiefs. Pagak, Memegwecio, and the northern "fairies" are well known. Among the types of divination common are scapulimancy, scrying, and the beaver haunch, and bear kneecap methods. Among the common types of magic are the use of the bezoar, of the foetal inclusion, and of singing and drumming, to bring luck in hunting; the use of the buzzer, the bull roarer, the singed rabbit skin, and feather plucking, to bring cold and wind; the use of caribou teeth, duck head feathers, bit of the navel string, miniature nets, and the shoulder blade of the mudturtle, as cradle charms.

At least six different types of medicine men are distinguished. The Midewiwin is still in fairly full force as well as the cylindrical tent conjuring. Disease is cured by the herbalists and by medicine men, the latter sucking out the disease by the use of hollow goose bones.

At death the soul crosses a river on a pole to the village of the dead. Infants are carried over by a swan. Kijé Manitu appears to be very much more clearly envisoned by the Rainy Lake and Lake of the Woods pagans than by the Cree and Montagnais tribes farther north and east. He is supposed to be good and benevolent, and to be, as one Indian expressed it, "boss of the whole thing."

On Tuesday, November 20, 1928, Dr. MATTHEW W. STIRLING, Chief of the Bureau of American Ethnology, spoke to the Society on *The Acoma Origin and Migration Legend.* This legend tells the story of two girls, children of the Sun, who were nurtured in the darkness within the earth. They were given by their father two baskets containing miniature images by means of which they were to create all living things on earth. On their emergence into the light they began this work, creating also the gods which were to be of use to the people. One of the sisters gave birth to twins, sons of the Rainbow.

Eventually the two sisters quarreled and separated, one, Nautciti, going away to become mother of the white people. The other, Iatiku, married Tiamûni, one of the sons of her sister, and remained to become mother of the Acoma people. Each of her daughters when born was given a clan name. After helping her children for many years Iatiku finally left them to their own devices, after having given them full instructions as to their proper religious observances. They were told that they must travel southward until they reached a place called Hako which was to be their permanent home. Seven times they stopped and built their pueblo only to have catastrophe overtake them, when they would move on. During these periods many of their medicine altars, ceremonies and societies had their origin. Their mythological heroes were born and had their adventures. Other gods were added to their pantheon. Finally Hako was located and the present Acoma built on the rock where it now stands.

At the meeting of the Society on January 15, 1929, Dr. JOHN R. SWANTON discussed *A Newly Discovered Southeastern Indian Dialect.* Dr. Swanton stated that in 1908 Mr. David I. Bushnell, Jr. had published in the American Anthropologist, under the title "The Account of Lamhatty," the story of a Tawasa Indian who had been carried off captive by a foreign tribe in 1707 and had escaped to the frontier settlements of Virginia. As much of his history as this refugee had been able to communicate, for none of the neighboring Indians understood his language, was taken down by the Virginia historian, Robert Beverely, and it was this narrative, preserved among the Ludwell Papers by the Virginia Historical Society, which Mr. Bushnell placed in print for the first time. More interesting still was the copy of a map by the same man found on the opposite side of the manuscript. Mr. Bushnell also reproduced this and attempted an identification of the place names entered upon it.

During the past summer Mr. Bushnell learned of a letter referring to Lamhatty in the archives department of the Virginia State Library. It had already been published but he also obtained a photostat copy of the original from Dr. McIlwaine, custodian of the archives. While doing this work Dr. McIlwaine discovered an English-Indian vocabulary of 60 words on the back of the document with the heading "Sum words of his language explained," and he furnished a photostat copy of this along with the letter. Both letter and vocabulary were by Col. James Walker, into whose hands Lamhatty had first fallen. The letter covers much the same ground as Bevereley's narrative; it is the vocabulary which is of especial interest. This, along with the rest of the material, was turned over to Dr. Swanton for examination. During most of their later history the Tawasa formed a constituent portion of the Alabama and it was naturally supposed that their language was close to if not identical with Alabama, a supposition rather increased by a study of the place names on Lamhatty's map. Yet the vocabulary developed the surprising fact that if it is representative of the speech of the Tawasa tribe, old Tawasa was a Timuquanan dialect, related to the now extinct tongues of central Florida. It was, however, intermediate between the tongues of the Muskhogean group—Creek, Choctaw, Apalachee, etc.,—and the dialects of Timuquanan hitherto known to us. Dr. Swanton illustrated these resemblances by means of slides. He believes that this material adds the final argument to an already formidable amount of proof that the Timuquanan and Muskhogean languages are genetically related and should be combined.

JOHN M. COOPER, *Secretary.*

## THE ENTOMOLOGICAL SOCIETY

### 405TH MEETING

The 405th meeting was held at 8:00 p.m., Thursday, November 1st, 1928, in the National Museum. President S. A. ROHWER presided. There were present 36 members and 20 visitors.

Mr. HERBERT H. ROSS, Assistant Entomologist, State Natural History Survey Division, Urbana, Ill., was elected to membership.

Mr. ROHWER, as Treasurer, stated that since the last meeting of the Society some of the outstanding obligations in connection with the entertainment of the foreign delegates to the 4th International Congress had been paid, but sufficient funds had not been collected yet to liquidate all of its indebtedness for this entertainment. He requested that members who have not responded to the request for funds give the matter their early consideration.

The president announced that a portion of the time immediately following would be set aside for consideration by the Society of the life and services of our recently departed Honorary President Dr. EUGENE AMANDUS SCHWARZ. He then called upon Dr. HOWARD, as Committee Chairman, to read a statement ordered by previous resolution of the Society and prepared by a Committee composed of L. O. HOWARD, H. S. BARBER, and AUGUST BUSCK. This is as follows:

> Your committee recommends that the following statement be recorded in the minutes of the meeting:
>
> The Entomological Society of Washington appreciates to the fullest degree that in the passing of Dr. Eugene Amandus Schwarz it has lost its most learned member, its most loyal and generous supporter, and the kindliest and most helpful of friends. The Society points with pride to the facts that Doctor Schwarz was one of its founders, that he held in the course of the years every office in which he could serve, and that the title Honorary President was created especially for him.
>
> The Society feels that American entomologists should be grateful that this great soul has lived among them for more than fifty years, constantly in his quiet way influencing their trend of thought towards the very best methods and towards sound scholarship.
>
> Signed: L. O. Howard, *Chairman.*
> H. S. Barber.
> August Busck.

A letter from Dr. NATHAN BANKS of Harvard University, Cambridge, Mass., to Dr. Howard, containing reminiscences and appreciation of Dr. Schwarz, was read by the Secretary and appropriate comments on it were made by Dr. Howard.

Dr. Howard then read a paper on Dr. Schwarz prepared by the above Committee, which will be published in full in a forthcoming memorial number of the Proceedings of the Entomological Society. Discussion of the paper and expressions of appreciation of the career of Dr. Schwarz were then given by MCINDOO, ALDRICH, HYSLOP, CLARK, HOWARD, BISHOPP, HALL, POPENOE, BUSCK, MARLOTT, MANN, WEBB, SASSCER, and CAMPBELL.

The filling of the position of Honorary President, made vacant by the death of Dr. Schwarz, was discussed by Mr. BUSCK, who directed attention to the fact that Dr. Howard was the logical member of our organization to fill this position. By unanimous vote of the Society, Dr. HOWARD was then

made Honorary President and was called upon to preside over the remainder of the meeting. Upon taking the chair he addressed the Society briefly and informally, expressing his happiness over the honor and dwelling upon his life-long enthusiasm for the science of entomology and his loyalty to the personnel of our membership.

*Regular program:* Dr. F. L. CAMPBELL: *Some facts about chitin.* The chemical and physical properties of chitin and methods for its detection were described and exhibited. The differences between chitin and cellulose were stressed, because of erroneous statements in the entomological literature that cellulose occurs in the entocuticula of insects. The source and spread of this error was pointed out. Both the entocuticula and exocuticula of insects in the sclerites and in the intersegmental membrane contain chitin. Neither layer has ever been shown to be free from chitin or to consist of pure chitin. Consequently, no areas of the insect cuticula are non-chitinized, so far as we now know. Chitin in the cuticula is always accompanied by more or less carbohydrates and proteins, and often pigments (called collectively "incrustations"). Since hard cuticula after alkali treatment becomes flexible, since the natural flexible entocuticula contains much more chitin than the hard exocuticula, and since hard structures (like the ootheca of the cockroach) do not contain chitin, it was concluded that incrustations, and not chitin, are the cause of the hardness of sclerites. It was shown also that depth of pigmentation is not related to the percentage of chitin in a surface structure and hence can not be used as an index of the extent of chitinization. Since neither hardness nor pigmentation are related to chitinization, it was recommended that the descriptive term "chitinized," long used to characterize hard, pigmented sclerites, be abandoned.

It was shown that chitin occurs in the egg shell of a cockroach and a grasshopper, when the shell consists of the blastoderm membrane and chorion. Chitin occurs only in the former structure. The report of Wester that the peritrophic membrane of the American cockroach is chitinous was confirmed and the significance of this fact pointed out.

The staining reactions of pure chitin were briefly discussed and it was pointed out that chitin stains best with acid dyes, cellulose with basic dyes. The presence of incrustations may alter staining reactions.

Facts from the literature on chitin were drawn upon for description of its distribution in plants and animals, its sameness wherever it is found, its decomposition in nature with special reference to its occurrence in fossil insects and its indigestibility by mammalian digestive enzymes, and, finally, its possible usefulness to man. (*Author's abstract.*)

At the conclusion of the reading of this paper and after discussion by SNODGRASS it was decided by the Society that, because of the lateness of the hour, it would be better to defer further discussion of it until the beginning of the next meeting.

The Society was especially happy to have with us for the evening a distinguished visitor, the widow of the late Dr. CHARLES V. RILEY, former Chief of the U. S. Bureau of Entomology, and, on suggestion of Dr. Howard, the members by rising acknowledged her presence and the honor of her visit.

### 406TH MEETING

The 406th meeting was held at 8 p.m., Thursday, December 13, 1928, in the National Museum. President S. A. ROHWER presided. There were present 26 members and 13 visitors.

Mr. ROHWER stated that sixty dollars was yet needed to reimburse those members who had advanced funds in connection with the entertainment following the Ithaca meeting.

Mr ROHWER also reported that at a recent meeting of the Executive Committee it was agreed to transfer the reserve supply of the Proceedings from storage space in the National Museum now needed for other purposes to free storage in the Lemon Building, 1729 New York Avenue, N. W., as soon as possible after January 1, 1929. In view of the fact that the Museum has furnished free storage since 1910, it was ordered that a letter of thanks be sent to the Museum authorities in appreciation of the favor.

*Regular program:* Dr. PAUL BARTSCH, of the U. S. National Museum: *Field experiences with Cuban insects.* He presented in outline a general survey of the principal localites covered by his trip, then related a number of individual instances of collections made here and there and exhibited specimens in alcohol of some of the material obtained. Emphasis was placed on observations of the relation of insects to other zoological forms, notably tarantulas, millipeds, and scorpions. Instances were related of capture of tarantulas by hunting wasps (*Pepsis obliquerugosa* Lucas); of strife between scorpions (*Centruroides gracilis* Latr.) and tarantulas; of excessive stinging from colonies of wasps; and of butterflies (*Heliconius charithonia* L.) eaten in large numbers in caves by bats. He reported also on experiences with large millipeds (*Julus* sp.) that exuded a strong fluid with staining and burning properties quite similar to those of concentrated iodine.

These remarks were discussed by SNODGRASS, SCHAUS, MCINDOO, BISHOPP, CAMPBELL, and EWING.

The next item of business was the regular annual election of officers for 1929. With BISHOPP and SASSCER as tellers the following were duly elected: *Honorary President:* L. O. HOWARD; *President:* J. E. GRAF; *First Vice-President:* A. C. BAKER; *Second Vice-President:* F. C. BISHOPP; *Recording Secretary:* J. S. WADE; *Corresponding Secretary-Treasurer:* S. A. ROHWER; *Editor:* W. R. WALTON; *Executive Committee:* The officers and A. N. CAUDELL, C. T. GREENE, T. E. SNYDER; *Representing the Society in the Washington Academy of Sciences:* A. G. BÖVING.

During intervals between votes on the election of officers, the paper entitled *Some facts about chitin*, by Dr. F. L. CAMPBELL, presented but not discussed at the last previous meeting due to lack of time, was brought up and discussed by SNODGRASS, EWING, ROHWER, HYSLOP, and CAMPBELL.

J. G. SANDERS, of the Sun Oil Company of Philadelphia, gave reminiscences of meetings of the Society some twenty years ago, at which time he had served as Corresponding-Secretary-Treasurer and had charge of the reserve supply of the Proceedings. He referred appreciatively to associations of those years with some of the older men, notably ASHMEAD, COQUILLETT, HEIDEMANN, KNAB, SCHWARZ, and PIPER.

J. N. TENHET, of Truck Crop Insect Investigations of the Bureau, located at Chadburn, N. C., spoke briefly of his work in that State on tobacco insects, notably *Monocrepidius vespertinus* Fab., and *Horistinotus uhleri* Horn. He also took opportunity to express his appreciation of the courtesies shown him by the Washington entomologists, notably HYSLOP and MORRISON. His observations on Elateridae were then discussed by HYSLOP.

C. F. W. MUESEBECK, of the Gypsy Moth Laboratory, Melrose Highlands, Mass., described some of the recent work on parasites being conducted at Budapest and at summer field stations in various parts of Europe. He

mentioned also some of the difficulties of the work, the matter of alternate host factors, and the actual sending of the parasites. His observations on these parasites were then discussed by ROHWER.

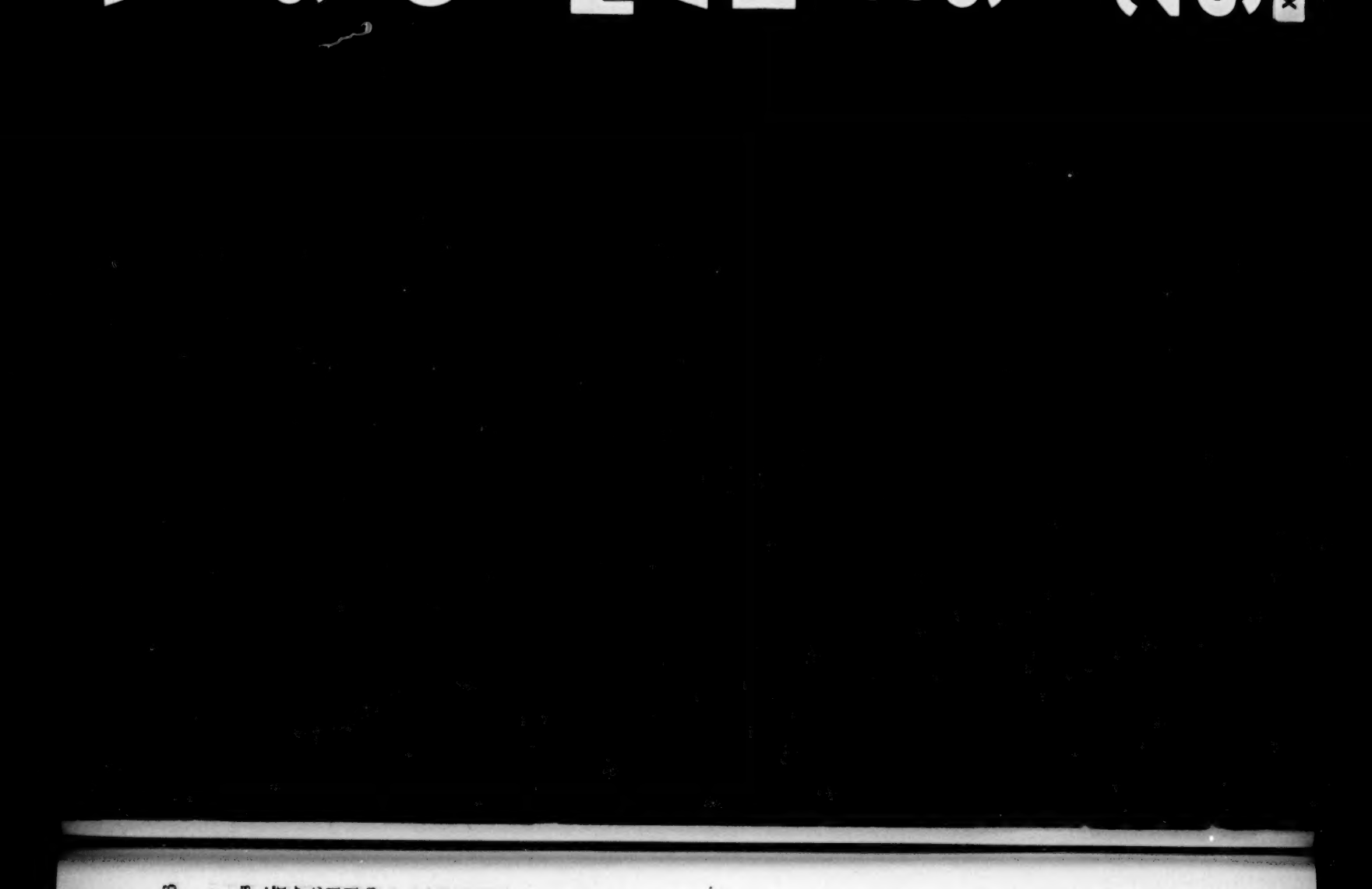
B. A. PORTER, formerly of the Bureau's field laboratory at Vincennes, Indiana, and now of the Washington office, greeted the society and expressed pleasure at being able in future to attend all our meetings.

Mr. ROHWER discussed briefly the situation regarding the pink bollworm, the status of the $5,000,000 appropriation authorized last year, and certain features in connection with the quarantine work. He stated that on November 22, 11 pink bollworm larvae had been found in a single field, 5 miles from Odessa, Ector County, Texas, and that 10 of these larvae were found in one single boll and of the 10, 7 were dead and 3 alive. Very intensive scouting was being done in the seven counties where pink bollworm was found last year. These are known as the Western Extension, being that part of Texas which has only during a comparatively recent period been devoted to the growing of cotton and which connects on the east with the main cotton belt of the South.

J. S. WADE, *Recording Secretary.*

## SCIENTIFIC NOTES AND NEWS

One result of the general prevalence of the "flu" during the last few months is seen in the extensive advertising of so-called remedies and alleviatives. The Food, Drug and Insecticide Administration of the U. S. Department of Agriculture, has listed over 650 preparations of this type and has already instituted action for misbranding under the Federal food and drugs act against approximately 114. Many manufacturers have voluntarily corrected their labelings to meet the requirements of the law. According to medical authorities there is no known drug or combination of drugs which constitutes a competent treatment for or preventive of influenza.

FRANK L. HESS, Chief Engineer, Rare Metals and Non-Metals Division, U. S. Bureau of Mines, expects to sail on the *President Cleveland* from San Francisco on March 15, on a professional trip which will take him to Shanghai, Canton, and other Chinese points, the Malay Peninsula, Burma, India, and probably Russia and other countries in Europe, returning to Washington about the end of the year.

The annual dinner of the Botanical Society of Washington was given March 12. Former Secretary and Mrs. W. M. JARDINE and Dr. and Mrs. BRANDES were honor guests at the reception; and Dr. BRANDES lectured on *Botanical Explorations in New Guinea*, illustrated with motion pictures.